DEVELOPMENT OF HIGH PRESSURE SPRAY TRIGGERING

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ABSTRACT

This project presents the study about development of high pressure spray triggering and control in a direct injection gasoline injector of a gasoline engine. The objectives of the study is to develop injection system using a parameters of time and pressure in order to identify the spray characteristics including spray angle, spray tip penetration and spray width. The scopes of this research is choosing control system EFI in type of injection, setup test rig for experimental using high pressure chamber and develop control and triggering system in order to control the timing and delay of the injector. After test rig fabrication is done and all equipment has been setup, experiment is done by supplying pressure from high pressure fuel pump to fuel injector that attach to high pressure chamber. Ambient temperature was set to 300 K and ambient pressure is 10 kpa, 20 kpa, 30 kpa and 40 kpa. Simple triggering and control has been developing using MATLAB Simulink and the DAQ software result was analyzed due to sample of calculation.

ABSTRAK

Projek ini menunjukkan kajian tentang membangunkan system tekanan tinggi kawalan semburan cecair dalam injektor petrol bagi enjin gasoline. Tujuan kajian ini adalah untuk membangunkan sistem kawalan dengan menggunakan parameter masa dan tekanan untuk mengenal pasti ciri-ciri semburan termasuk sudut semburan, penetrasi semburan dan lebar semburan. Ruang lingkup dalam penelitian ini adalah memilih sistem kawalan mengikut jenis injektor, menyediakan rangka ujian bagi melakukan eksperimen dengan menggunakan kebuk bertekanan tinggi dan membina sistem kawalan untuk mengawal masa dan kelewatan Injektor. Setelah fabrikasi rangka ujian dilakukan dan semua peralatan telah disediakan, eksperiman dilakukan dengan membekalkan tekanan dari pam bertekanan tinggi ke injektor yang terletak di kebuk tekanan tinggi. Suhu persekitaran ditetapkan untuk 300K dan tekanan diberi sebanyak 10 kpa ,20 kpa, 30 kpa dan 40 kpa. Sistem kawalan injektor dibina menggunakan aturcara MATLAB Simulink dan perisian DAQ dianalisis keputusan dibandingkan dengan penyelidikan terdahulu dan contoh pengiraan.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF SYMBOLS

P	Normal pressure
P_o	Normal pressure constant
P_t	Total resultant load (Tensile)
P_c	Total resultant load (Compression)
E	Young’s modulus
$\mathbf{K}$	Stiffness matrix
$\mathbf{u}$	Vector of displacements
$\mathbf{f}$	Vector of applied forces
x	Relative density
ρ	Density
c	Compliance
x	Stiffness
g_e	Design variable

LIST OF ABBREVIATIONS

GDI	Gasoline Direct Injection
ECU	Electronic Control Unit
EFI	Electronic Fuel Injection
Fps	Frames Per Second
DAQ	Data Acquisition Toolbox
FE	Finite element
FEA	Finite Element Analysis
FEM	Finite element modelling
HEXA	Hexahedral
IC	Internal Combustion

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Fuel injection control system directly affects the fuel efficiency and pollution level or substances that can be used as fuels of automotive engines, other than conventional fuels. The benefits of these alternative fuels are that they emit less air pollutants and they are very economical compared to conventional fuels .Since 1970s, the environment pollution and energy consumption has become serious concerns associated with engine control technology. The self-tuning control technique is applied to improve the engine performance by controlling the engine speed and exhaust flow. Most fuel injection systems are for gasoline or diesel applications. With the advent of electronic fuel injection (EFI), the diesel and gasoline hardware has become similar. EFI's programmable firmware has permitted common hardware to be used with different fuels.

For this design, it is necessary to investigate the spray development process, the ignition probability, and the combustion propagation process of Combustion Natural Gasses. In this study, a combustion chamber with a visualization system is designed and built. CNG is injected into the combustion chamber by a gasoline direct injection (GDI) injector and ignited by a spark plug placed near the injector. The close arrangement of the injector and spark plug provides a stratified charge of CNG around the spark discharge position. Images of the CNG spray development and combustion propagation processes were digitally recorded. The results of this study can contribute important data for the design and optimization of spark-ignited direct injection (SIDI) CNG engines.

1.2 PROBLEM STATEMENTS

In most spray applications, spray characteristics, such as droplet size and distribution, are highly dependent on the specific spray nozzle used, control in the system which makes it difficult to alter them without a complete overhaul of the system. The implementation of spray control that could enable manipulation of spray behavior and parameters, as necessary, would enhance the versatility and efficiency of sprays.

1.3 OBJECTIVES OF PROJECT

The objectives of the study are:

i. To study about fuel injection system.
ii. To design and integrate of the programming part to control injector fuel spray.
iii. To develop a triggering and control system based on time and pressure.

1.4 SCOPE OF PROJECT

There are three scopes in this study:

i. Study on fuel injection triggering and control system.
ii. Develop and setup test device use DAQ software for triggering.
iii. Develop simple triggering and control using MATLAB Simulink

1.5 OUTLINE OF REPORT

Chapter 1 introduces the background, problem statement and the scopes of this study. Chapter 2 presents the literature study about injector, Matlab simulink and spray of the injector pressure. Chapter 3 discusses the development of injector pressure modeling, DAQ software and the optimization technique. Chapter 4 discusses the results and analysis of the Matlab , and optimization of the injector pressure. Chapter 5 presents the conclusion and recommendation of the future work.

1.6 SUMMARY

The project background, objective, problem statement, and project scope was very important in order to guide me follow the project cover. While the project flowchart was guide me to complete the work at the time given.

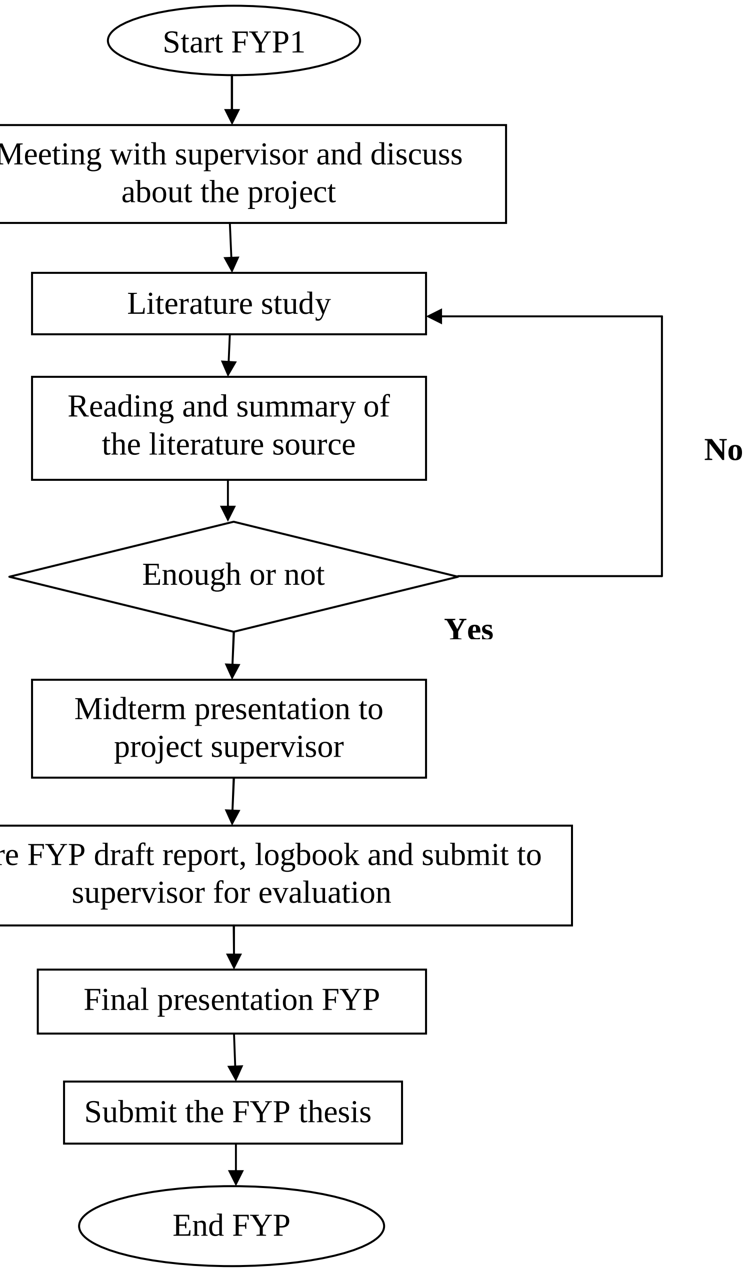

Figure 1.2: Project flowchart

CHAPTER 2

LITERITURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide information which related to the injector pressure, Matlab simulink , DAQ software component and also about Maximum of EFI injector pressure . The research concludes about fuel injection system, control mechanism and spray behaviors.

2.2 FUEL INJECTION

In modern automotive internal combustion engines, the varieties of injection systems have existed. A fuel injection system is designed and calibrated specifically for the types of fuel it will handle. Most fuel injection systems are for gasoline or diesel applications. With the advent of electronic fuel injection (EFI), the diesel and gasoline hardware has become similar. EFI's programmable firmware has permitted common hardware to be used with different fuels.

Basic components in fuel injection system are fuel injector, high speed camera and electronic control unit (ECU) such as injector driver and digital delay generator for the signal line while other components such as fuel tank, fuel filter, high pressure pump and pressure regulator for the fuel line. In the laboratory experiment, high pressure chamber is used as a main character in order to identify spray patterns. Some of the experiment that using high speed camera can trigger with personal computer and ECU. The data gained will show in the personal computer automatically.

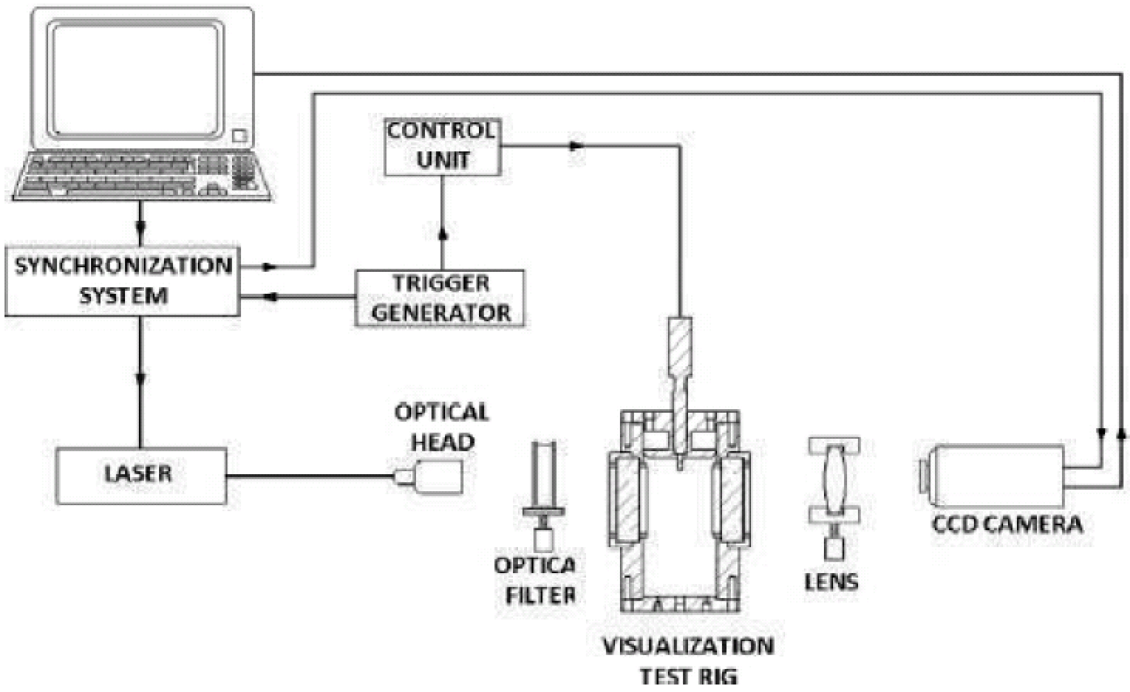

Figure 2.1: Fuel injection system

Source: J.M Desantes, 2009

2.2.1 Fuel Injector

Fuel injectors are nozzles that inject a spray of fuel into the intake air. They are normally controlled electronically, but mechanically controlled injectors, which are cam operated, also exist. A metered amount of fuel is trapped in the nozzle end of the injector, and a high pressure is applied to it, usually by a mechanical compression process of some kind. At the proper time, the nozzle is opened and fuel is sprayed into the surrounding air. The amount of fuel injected each cycle is controlled by injector pressure and time duration of injection. An electronic fuel injector consists of the following basic components which is valve housing, magnetic plunger, solenoid coil, helical spring, fuel manifold and pintle (needle valve). When not activated, the coil spring holds the plunger against its seat, which blocks the inlet flow of fuel. When activated, the electric solenoid coil is excited, which moves the plunger and connected pintle (needle valve).

This opens the needle valve and allows fluid from the manifold to be injected out the valve orifice. The valve can either be pushed opened by added pressure from the plunger or it can be opened by being connected to the plunger, which then releases the pressurized fuel. Each valve can have one or several orifice openings. In mechanically controlled injectors there is no solenoid coil and the plunger is moved by the action of a camshaft.

Figure 2.2: Fuel spray for combustion system

Source: www.enginebasics.com/Engine Basics Root Folder/Fuel Injectors 2

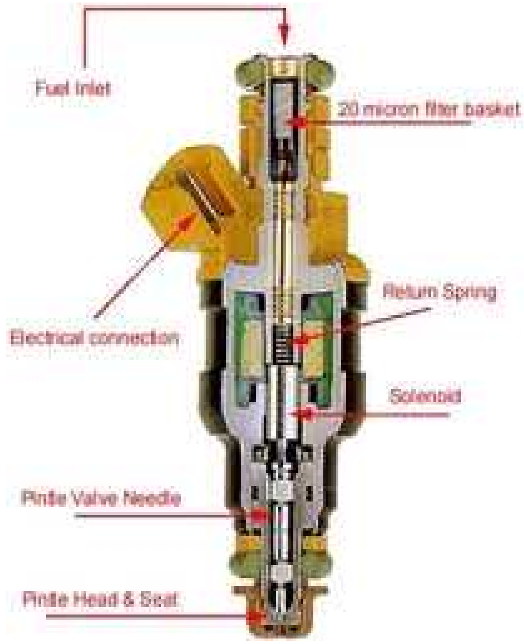

Figure 2.3: Fuel Injector

Source: Lee, C.S 2009

2.2.2 High speed camera

In order to get different spray characteristic in term of different timing and pressure controlled by ECU, it is require a high speed camera. An example of high speed camera that mostly use is Photron, Fastcam-APX-RS. This camera provides full megapixel resolution images at frame rates up to 3,000 frames per second (fps), 512 x 512 pixels resolution at 10,000 fps and at reduced frame rates to an unrivaled frame rate of 250,000 fps. Utilizing Photron's advanced CMOS sensor technology, the APX-RS provides the higher light sensitivity than any other comparable high-speed imaging system. Both color and monochrome models are available, both with excellent anti-blooming capabilities. A user selectable 'Region of Interest' function enables the active image area to be defined in steps of 128 pixels wide by 16 pixels high to allow the most efficient use of frame rate, image resolution and memory capacity for any event. Up to 20 commonly used configurations can be saved to memory for future operation. Available with Gigabit Ethernet, Fire wire and fiber optic communications, this compact camera can provide exposure durations as short as 2 microseconds and is easily operated in the field with or without a computer through use of the supplied remote keypad, enabling full camera setup, operation and image replay.

Figure 2.4: High speed camera

Source: Photron 2010

2.2.3 Injector driver

Injector driver modules work with the central computer system and the fuel injection system in a vehicle. Only vehicles with fuel-injection systems will use an injector driver module. Engines that need high pressure fuel injection rely on injector driver to control the fuel injection system. The main purpose of an injector driver is to control the amount and timing of fuel injection within the vehicle's system.

Figure 2.5: Injector Driver

Source: www.thunderracing.com

2.2.4 Digital delay generator

Digital delay generator is a piece of electronic test equipment that provides precise delays for triggering, syncing, delaying and gating events. It is used in many types of experiments, controls and processes where electronic timing of a single event or multiple events to a common timing reference is needed. Similar to a pulse generator in function but with a digital delay generator the timing resolution is much finer and the delay and width jitter much less.

Figure 2.6: Digital delay generator

Source: www.highlandtechnology.com

2.3 CIRCUIT 555 TIMER IC

The 555 Timer IC is an integrated circuit (chip) implementing a variety of timer and multivibrator applications. The IC was designed by Hans R. Camenzind in 1970 and brought to market in 1971 by Signetics (later acquired by Philips). The original name was the SE555 (metal can)/NE555 (plastic DIP) and the part was described as "The IC Time Machine". It has been claimed that the 555 gets its name from the three 5 kF resistors used in typical early implementations, but Hans Camenzind has stated that the number was arbitrary.

Figure 2.7: NE 555 IC

Source: Lubkin, G.B. 1996.

2.4 SPRAY CHARACTERISTICS

The microscopic spray characteristic including axial spray tip penetration, spray width and spray angle are shown in figure 2.6. The spray tip penetration and spray width were defined as maximum distance from the nozzle tip of the side view spray image and maximum radial distance from the bottom view, respectively. Also the spray cone angle is defined as the interval which is formed by the nozzle tip and two straight lines wrapped with the maximum outer side of the spray. Amirruddin, A.K. (2009) says that the higher ethanol contains the spray spread faster, present longer penetration distance.

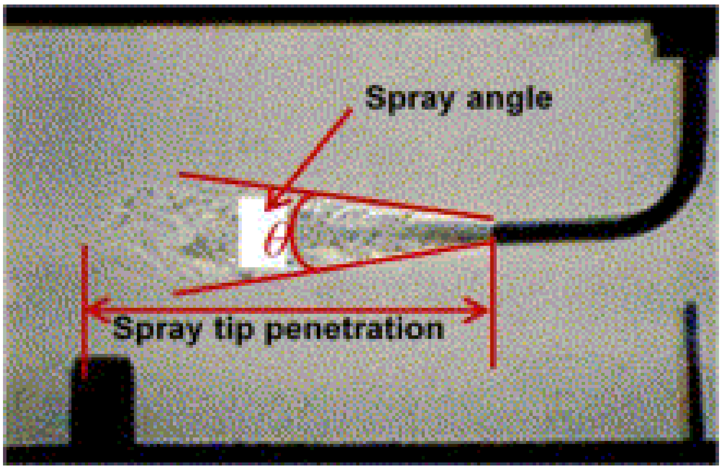

Figure 2.8: Definition of spray characteristic (sprays tip penetration, spray width and spray angle)

Source: Lee, C.S et al. 2009

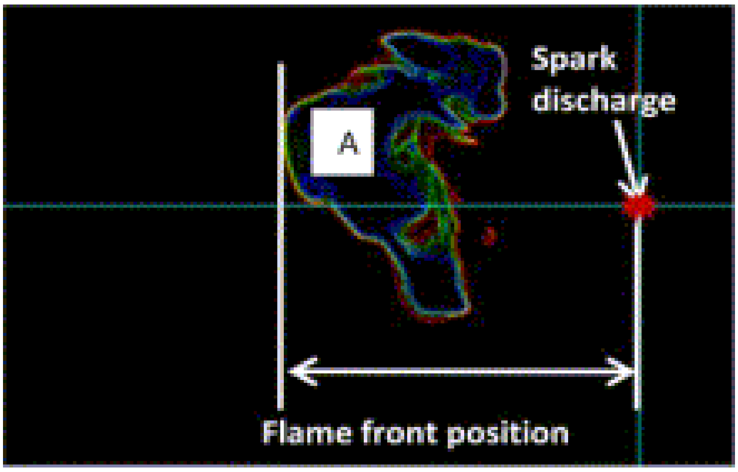

Figure 2.9: Definition of spray characteristic (flame front position)

Source: Lee, C.S et al. 2009

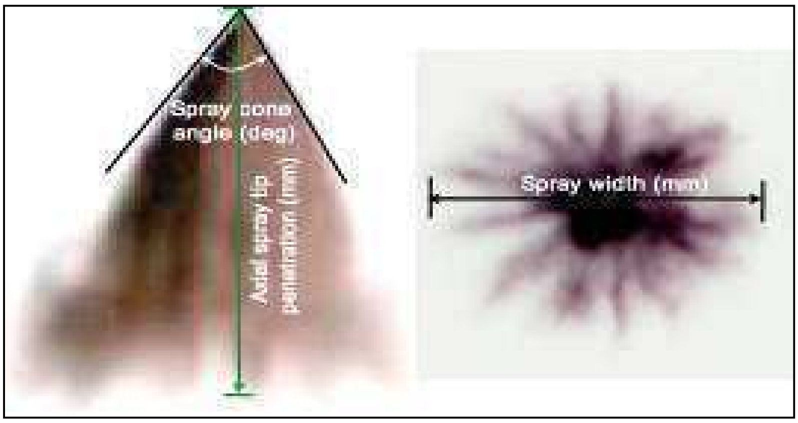

Figure 2.10: Definition of spray characteristic (spray width and spray angle)

Source: Lee, C.S et al. 2009

An evaluation of the correlations between spray tip and function of time, indicated that the formula developed by Dent, best predict the equation:

$$S = 3.07 \, (P/\,p)^{1/4} \, (tdn)^{1/2} \, (294/T)^{1/4} \quad (2.1)$$

Where P, pressure across the nozzle, p, density of fuel, t, time after start of the injection, d, diameter of nozzle and T, ambient temperature.

2.5 CONCLUSION

This chapter has been the summary of previous works that related to this project. The works were discussed are about spray triggering, spray penetration and spray characteristic of injector. The next chapter will be discussed about the methodology of this project.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter presents the overall methodology of the optimization based on high pressure spray triggering. The optimization is the most critical combustion process in the automotive industry. It is very important that any production company invested millions of their profits into Research and Development (R&D) the engine. The aim of this chapter is to develop a methodology to improve the injector pressure spray process of high pressure spray triggering.

3.2 THEORETICAL BASIS OF INJECTION

The injection system used for this study was a common rail, electronically controlled unit injector system. The system was constructed on a moveable cart and the injector was mounted on a constant volume spray chamber. The injection system included a fuel pumping system, a lubrication system, an injector, and a control system. Figure 3.1 and 3.2 shows the connections between these components. The high pressure fuel pump was a multiplelobe, cam jerk type fuel injection pump which was driven by an electric motor. The pump pressurized the fuel inside an accumulator (common rail) to pressures up to 80 kpa. However, 40 kpa was used as a maximum pressure for the experiments as to ensure the reliability of fuel system components. The injection pump was lubricated by a separate oil lubrication system which contained an oil sump, a hydraulic pump, a flow controller, and a pressure controller. Fuel metering was done with a three way valve at the injector. The function of the three-way valve was to switch the nozzle fuel pressure between the common-rail pressure and atmospheric pressure. Injection timing and quantity were controlled by changing the timing of the pulse and the pulse width applied to the three-way valve. The nozzle tip was a 6-hole, mini-sac type of diesel injector tip. The hole diameter was 0.26 mm and the length was 0.5 mm, which makes the nozzle L/D ratio about 1.923. There were two electronic control units to control this injector, an injector controller and a pump controller. These controlled the injection timing, injection duration, injection quantity, injection rate, and injection pressure of the injector. The injection timing and injection duration for each split injection was adjusted independently using the injector controller. The injection pressure was controlled from the pump controller.

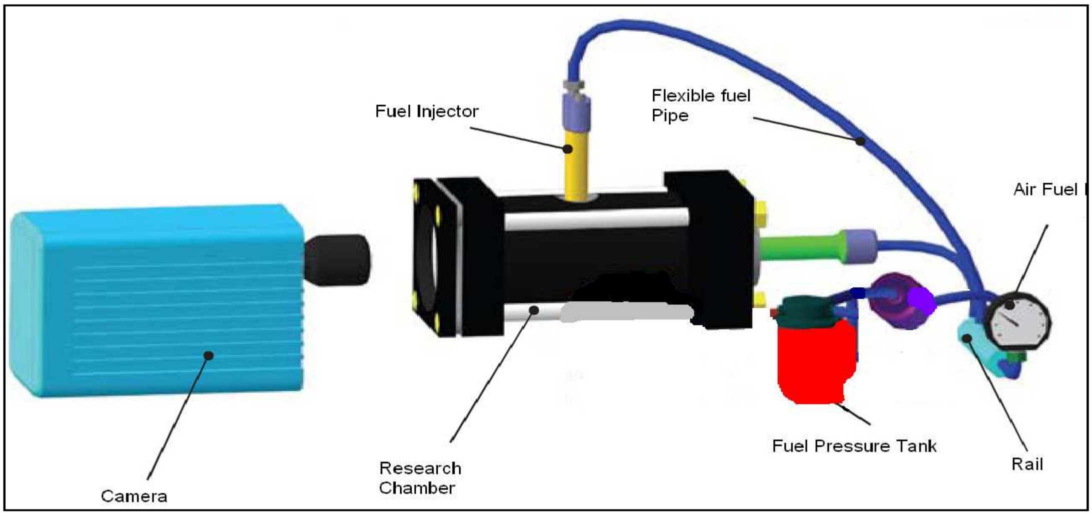

Figure 3.1: Experimental setup

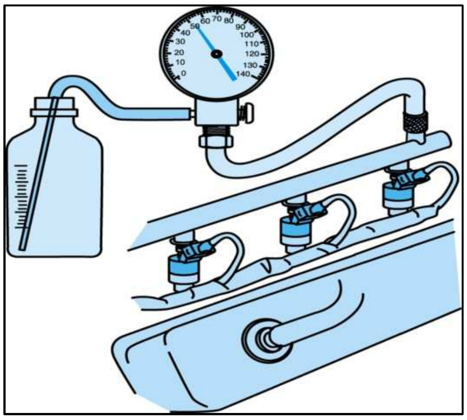

Figure 3.2: Connecting of injector